THE ROLE OF CRITICAL DISCOURSE IN TEACHER LEARNING: A CASE STUDY

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The scene one might discover upon walking into many traditional math classrooms differs greatly from the picture painted by the National Council of Teachers of Mathematics (NCTM) in their vision of "learning with understanding":

> Students confidently engage in complex mathematical tasks chosen carefully by teachers... Teachers help students to make, refine, and explore conjectures on the basis of evidence and use a variety of reasoning and proof techniques to confirm or disprove those conjectures. Students are flexible and resourceful problem solvers. Alone or in groups… they work productively and reflectively, with the skilled guidance of their teachers…They value mathematics and engage actively in learning it (NCTM, 2002).

The ideal math classroom envisioned by NCTM places a high degree of emphasis on mathematical knowledge and requires the teacher to become a facilitator of students' learning rather than the holder of correct answers. It is a classroom in which students' ideas about math are at the forefront of instruction and students' interactions with the content create a knowledge base from which their expertise and confidence grows. This type of classroom also places teachers in a position where they cannot rely solely on the curriculum or textbook to generate mathematical meanings. They must interact with the material themselves in order to facilitate students' learning.

The current standards movement promoted by the NCTM demands that teachers draw out students' understandings of complex and fundamental mathematics concepts. Both veteran and novice teachers are faced with the challenge of modifying their understanding of and beliefs about mathematics in order to achieve the goals outlined in the standards. A school or district that implements a reform-oriented curriculum, which is designed to change teaching practice, must be prepared to provide support for teachers that addresses the complexity of such a transformation. A change in curriculum in this case calls for a new approach to mathematics and teaching. Therefore, implementing a

reform-based curriculum requires teacher learning, which includes both the acquisition of new understandings of math concepts and the formation of new pedagogical beliefs for practice.

The variety of beliefs and understandings that teachers hold which affect the way they read, interpret, and enact the curriculum in their classrooms includes 1) teachers' beliefs and understandings about math, 2) teachers' beliefs and understandings about learning and teaching, 3) teachers' conceptions and use of curriculum, and 4) teachers' awareness of the need for change in practice and willingness to attempt change (Brown, 2000; Remillard, 1999, 2000; Freeman and Porter, 1989; Ball and Cohen, 1996; Wilson and Berne, 1999; Collopy, 2003; Fennema and Nelson, 1997; Hargreaves, 1994; Lloyd, 1999; Putnam, 1992; McLaughlin, 1976; Smith, 1996; Smith, 2000; Spillane, 2000). Research on teachers' implementation of curriculum supports the argument that teachers must be presented with, be able to recognize, and wish to act on "learning opportunities" that allow teachers to reflect on, question, and alter their beliefs and understandings (Remillard and Bryans, under review).

To understand the changes that need to occur in teachers' thinking, it is helpful to collapse the broad range of curricula types into two main categories: traditional and standards-based. "Traditional" curricula, such as the "new math" of the late 1950s and 1960s as well as the "back-to-basics" of the 1980s, refer to programs of instruction that 1) hold the teacher and the textbook as the sole authorities for right answers, 2) focus on memorizing procedures, 3) emphasize mechanical answer finding, and 4) treat mathematics as a body of isolated concepts and procedures (LeCampagne, p.5). "Standards-based" curricula or "reform-oriented curricula" on the other hand, are those

programs that call for the alignment of instruction to the standards proposed by the NCTM. These standards imply fundamental shifts from traditional curricula and are characterized by 1) using logic and mathematical evidence as verification, 2) mathematical reasoning, conjecturing, inventing, and problem solving, and 3) connecting mathematics, its ideas and its applications (LeCampagne, p. 6). Juxtaposing these two curricula types illustrates the degree of change in instruction that is expected to take place when a standards-based curriculum is introduced.

Teachers' awareness of the need for change in practice and their willingness to attempt change may indeed be the most crucial factors in the implementation of a reform curriculum. Likewise, they are also the most difficult obstacles to overcome. As David Cohen (1990) argues, teachers are both the objects and the agents of change. Teachers who have been teaching a "traditional" curriculum must themselves acquire new mathematical and pedagogical knowledge to enact a reform-based curriculum. Their willingness and capacity to adapt to a new curriculum determines the degree to which change in instruction occurs (Woodbury, 2000).

Remillard and Bryans (under review) contend that teachers with different orientations toward using curricula realize different opportunities for learning within them and therefore experience varying degrees of change in their teaching practice. They define learning opportunities as "events or activities that are likely to unsettle or expand teachers' existing ideas and practices by presenting them with new insights or experiences" (p.28). Applying this and other definitions of teacher learning, I explored the kinds of learning opportunities that can support teachers' learning as they use one

standards-based curriculum in particular, *Investigations in Number, Data, and Space* (TERC, 1998).

One way teachers learn to use a new curriculum is through "critical discourse," a concept developed from the literature on teacher learning, teacher beliefs, and teachers' use of curriculum. One definition of critical discourse is discussion in which teachers consider the merits and demerits of their practices, beliefs, and understandings accordingly, and make connections between their understanding of new content and their pedagogical beliefs. Not surprisingly, it is helpful for teachers to have first hand experience with the kinds of learning that the NCTM imagines for students (Remillard and Bryans, under review). Traditional teachers will need to reconsider the content of mathematics and imagine new ways of presenting or extracting meaning from students' ideas while confronting their own conceptions of the mathematical concepts and skills.

Sadly, traditional professional development programs often do not acknowledge the importance of critical discourse, and instead rely on techniques that gloss over contentious issues (Ball, 1994; Ball & Cohen, 1995; Collopy, 2003; Wilson & Berne, 1999). Professional development programs, in all their variety, should foster learning opportunities for teachers that allow for and encourage critical discourse. Three important characteristics that are likely to lead to critical discourse are 1) ongoing forums which provide sustained support, 2) forums that address content relevant to the curriculum, and 3) those that are applicable to practice, especially those that model the instruction envisioned by the developers of the NCTM standards. In short, goals and expectations for teacher preparation should mirror those for student learning, and encourage the same level of interaction, problem solving, and reflection.

In this paper, I will explore the importance of critical discourse in the experience of one fourth grade teacher as she learned to use the standards-based curriculum, *Investigations*. A close examination of this case study demonstrates how critical discussion about mathematics might promote teacher learning and lead to teaching practices that are more compatible with the student learning outcomes as presented in the NCTM Standards. Reviewing the literature on the waves of math reform leading up to the standards movement will frame the current pressure for the adoption of state academic standards and set the stage for this particular case study. Following this history will be a discussion of the literature that conceptualizes how teachers approach and affect curriculum according to their beliefs and understandings. Finally, I will discuss the policy implications of research on teacher development that complements the implementation of a reform-based curriculum.

Brief History of Major Math Reforms leading up to the Standards Movement

In the last century, mathematics education in the United States has undergone three major "surgeries" that have attempted to alter systemic insufficiencies in the mathematical abilities of the nation's children. The first of these transformations occurred as formal public education in this country reached its 50th birthday. Prior to this time, only a few advanced students studied higher mathematical concepts and just as few students finished high school (Findell, 1996).

In the middle of the 20th century, following World War II, the launching of the Russian spacecraft Sputnik created international pressure for the United States to increase the quantity and quality of scientists and mathematicians. Schools were inundated with curriculum materials for what was referred to as the "new math." These curricula, which

were developed by mathematicians, showed little concern for the cognitive development of students or the mathematical capacities of teachers. Their goals were to bring students to an understanding of mathematical language and universal concepts, which resulted in something as complicated as set theory or number theory being used to explain simple computation such as addition or multiplication (Findell, 1996). This movement coincided with the mood of the larger society that intellectualism and "reasoned man" would resolve society's problems such as poverty and crime (Cooney, 1988). It was believed that if the structure of mathematics and other disciplines could be taught and learned, then all else would fall into place.

It is difficult to measure the impact of this movement, since evaluative research in classrooms has been scant until recently. However, test scores and international comparisons failed to show any large scale improvement in student competence. In response, the 1970's saw a movement known as "back to basics" where stress was placed on computation and objectives were behavioral in nature. For example, students were required to master the "basic" operations of multiplication and addition before moving on to math concepts that required higher order thinking. It was not until the end of the decade that the National Council of Supervisors of Mathematics identified ten math skills that were meant to give meaning to the applications of the computational abilities children had gained from the back to basics curricula (Findell, 1996). Without attention to when or how to use the computation methods, the math the students had learned was disconnected from any useful application.

The combination of these two failed efforts at systemic curriculum change has led to the current movement for standards-based education. In 1980, the National Council of

Teachers of Mathematics published an Agenda for Action which suggested, among other things, an increased emphasis on problem-solving that reflected real-life situations. They stressed that more students should learn more mathematics, and that a wider range of measures needed to be developed in order to evaluate mathematical knowledge (Findell, 1996). The NCTM was also an early group to suggest adopting standards for teaching and learning mathematics. Moreover, these standards would apply to all children, and set minimum competencies for children at all levels of schooling.

As mentioned previously, these standards call for shifts in the nature of instruction from 1) holding the teacher and the textbook as the sole authorities for right answers to using logic and mathematical evidence as verification, 2) from focusing on memorizing procedures and emphasizing mechanical answer-finding to mathematical reasoning, conjecturing, inventing, and problem solving, and 3) from treating mathematics as a body of isolated concepts and procedures to forming connections between mathematics, its ideas and its applications (LeCampagne, p.5). *Investigations*, the standards-based curriculum used by the teacher in this study, reflects these shifts in the introduction to each unit: "to offer students meaningful mathematical problems, to emphasize depth in mathematical thinking rather than superficial exposure to a series of fragmented topics, to communicate mathematics content and pedagogy to teachers, and to substantially expand the pool of mathematically literate students" (TERC 1998).

To meet these goals, comparable goals for teacher learning must be upheld. Depth in mathematical thinking and constructing meaning from math concepts requires considerable effort on the part of teachers, especially those elementary school teachers who are made uncomfortable by mathematics. The *Investigations* curriculum wishes to

communicate mathematics content and pedagogy to teachers, but as we will see from the research, there is more to changing practice than offering a new curriculum, even if it is one committed to drawing out teachers' understandings of mathematics, learning, and teaching.

The Importance of Teachers' Beliefs and Understandings of Mathematics, Teaching, and Learning

Research on the potential for reform-oriented curricular materials to create change in teaching practice has conclusively reported that changing the curriculum alone will not automatically lead to a change in instruction. There are many additional factors to consider in a place as dynamic as a math classroom. In addition to the "intended curriculum" of the textbook, ideas from teachers and perceptions from students come into play in the creation of the "enacted curriculum" which emerges as these ideas converge in the classroom environment (Remillard and Bryans, p 3; Remillard, in preparation, p. 4). Before, during, and after any given lesson, ideas about math, teaching, and learning mingle with the curriculum materials. Therefore, research shows the limits of a reform curriculum and points to the importance of opportunities for teacher learning in the implementation of a new curriculum. What follows is a review of a small but representative sample of the literature on teacher learning (Cochran-Smith and Lytle, 1999; Russell et al., 1995; Remillard and Bryans, under review) and teachers' use of curriculum (Remillard 1999, 2000; Brown, 2002). These works describe the variety of factors that influence teachers' practice, including beliefs and understandings of mathematics, teaching, and learning.

Cochran-Smith and Lytle (1999), in their synthesis of the literature on teacher learning, emphatically state that "teacher learning begins with identifying and critiquing

one's own experiences, assumptions, and beliefs" (p. 279). They break down knowledge into three categories: knowledge *for, in,* and *of* practice. Knowledge *for* practice covers "formal knowledge" such as subject matter, educational theory, pedagogy, and instructional strategies (p. 254). Knowledge *in* practice is the practical knowledge of teaching and encompasses the spontaneous nature of teaching and the knowledge that teachers apply as they enact the curriculum. Knowledge *of* practice is described by the authors as the exploratory and transformable knowledge of teachers. It is neither a melding of the first two types of knowledge nor completely exclusive of them. It is a critical approach to teaching and learning which breaks away from the tradition of learning what is already known.

Additionally, knowledge *of* practice occurs as teachers actively engage themselves and their students in critical learning. At the center of this type of knowledge is collaborative learning in "inquiry communities" (Cochran-Smith and Lytle, p.271). The literature on learning through inquiry concentrates on a search for meaning, problematizing the roles teachers play in designing and implementing initiatives for their own learning. Therefore, teachers who embrace knowledge *of* practice, and thereby engage in critical discussion around their teaching practices, are likely to alter their teaching practices based on their experiences.

Similarly, Russell et al. (1995) define teacher learning as an "ongoing and gradual process in which understanding of familiar content is deepened as one makes new connections and distinctions" (p. 10). They provide three examples of teachers engaged in learning mathematics. These teachers explored mathematics content, thought through students' representations and strategies, and looked underneath students' confusions or

excitement to consider mathematical structures (p. 10). Russell et al.'s analysis of the ways in which elementary school teachers learn mathematics in the context of their own teaching, revealed several elements necessary for teacher learning. These elements include teachers "seeing themselves as adult learners of mathematics and seeing their own classrooms as contexts in which they learn" and "assuming that the way to learn mathematics is to do mathematics" (p. 14). Russell et al. reason that as teachers consider student strategies and representations that are different from their own, they become aware of new aspects of mathematical relationships (p. 15). Their assertions parallel the findings of Remillard and Bryans (under review).

Research by Remillard and Bryans (under review) has also provided support for the idea of critical discourse, in this case between teachers and their students. Their research demonstrates the way in which opportunities for learning arise during the enactment of the curriculum in the classroom. They state that "teachers' ideas about mathematics, teaching and learning were challenged and altered when they examined unfamiliar mathematical tasks and interpreted students' work on them while teaching" (p. 4). Since standards-based curriculum encourages teachers to interact with students and their ideas as they arise, teachers are likely to come across very different understandings of mathematics among students. While attempting to relate to the students' understandings, teachers must reconsider their own conceptions of mathematics. Remillard and Bryans (under review) discovered that the teachers "found themselves exploring practices, struggling with mathematics, and confronting student thinking in ways that were unfamiliar" (p. 28) that led to the establishment of learning opportunities on which the teachers capitalized.

Remillard and Bryans' definition of learning opportunities includes any "events or activities that are likely to unsettle or expand teachers' existing ideas and practices by presenting them with new insights or experiences" (p 28). This broad definition can be applied to forums outside of the classroom, including when teachers are reading the curriculum materials and planning instruction. Remillard and Bryans further break down this definition into four categories of learning opportunities: 1) expanding the repertoire of activities, 2) gaining insights into students' thinking, 3) exploring mathematics, and 4) constructing the teacher's role in orchestrating student learning. The first category, expanding the repertoire of activities, addresses the use of curriculum through adopting and adapting tasks. Here, teachers integrate new tasks into pedagogical practice. This practice does not demand teacher learning, and in some cases severely limits it because a teacher does not need to challenge her ideas in order to mechanically apply new activities. However, as teachers adapt activities that are foreign to them, there is a possibility that they could develop and expand their repertoire, particularly over time.

Learning opportunities created by gaining insights into students' thinking tend to be connected to those created by exploring mathematics. Insights into students' thinking allow teachers to see the way students are learning and to change their practice to meet their students' needs. Probing students for explanations also requires teachers to understand mathematics as their students are conceptualizing it, and in order to provide feedback, teachers must constantly improvise. Their improvisations are a result of the complex process of recognizing students' perceptions of the mathematics content, which simultaneously requires the teacher to recognize her own perceptions of the mathematics content. For example, Remillard and Bryans (under review) mentioned one teacher who

learned more about her students by increasing the use of student explanation and her tendency to probe their thinking and try to make sense of their ideas (p. 31). This sort of probing led the teacher to further explore the meanings behind mathematic concepts. Subsequently, this is precisely the kind of activity reformers envisioned: "As they facilitated their students' work on the mathematical tasks in the curriculum, they found themselves contemplating and often struggling with the underlying concepts" (Remillard and Bryans, p. 32).

Constructing the teacher's role in orchestrating learning is the final category established by Remillard and Bryans. This opportunity is available primarily to those teachers who are "thorough piloters" of the curriculum, and who use all parts of the curriculum guide to prepare themselves for new lessons that challenge their mathematical and pedagogical beliefs and understandings. The improvisation described above became a regular part of these teachers' practice. As the authors stated, "Not only did they read the guiding suggestions and background information in the curriculum, but also they found themselves constructing new practices on the spot" (p.32). This category embodies the concept of student-centered learning, where the teacher is a facilitator in the co-construction of knowledge rather than an all-knowing authority on the subject.

In this way, enacting the curriculum leads to teacher learning. However, generalizing this result has led districts and schools to adopt new curricula in the hopes of altering teaching practice and in turn improving student achievement. While the curriculum is an important aspect in affecting teaching practice, I argue and later demonstrate in a case study the importance of teachers being supported in learning to use a new curriculum to fulfill its potential. One aspect of supporting that learning is

providing teachers with opportunities to engage in critical discourse about the content and pedagogical goals of a curriculum and their instruction.

Also in this article, Remillard and Bryans (under review) suggest that there are three ways that teachers use the curriculum that can impact the learning opportunities teachers create for themselves. These three categories of curriculum use are intermittent and narrow, adopting and adapting, and thorough piloting. They appear in a continuum from little to extensive use of the curriculum, and the categories also capture some of the other factors that impact how a teacher uses the curriculum. For instance, teachers in the "intermittent and narrow use" category use the materials minimally, relying on their own teaching routines and other resources to guide their curriculum map throughout the year. Adopting and adapting, on the other hand, applies to those teachers who use the materials as a guide for the general structure and content of their mathematics curriculum. Teachers in this category might have varying degrees of change in practice, as previously addressed in the discussion on learning opportunities. Teachers who adopt a new curriculum simply by expanding their repertoire of activities may or may not be presented with opportunities for learning.

The third category of curriculum use that Remillard and Bryans (under review) present is thorough piloting. Since this category includes exploring practices, struggling with mathematics, and confronting student thinking in ways that are unfamiliar to teachers, it is closely connected with those teachers who find learning opportunities by gaining insight into students' thinking, exploring mathematics, and constructing the teachers' role in orchestrating learning, as previously presented.

Remillard has done extensive work in this area and has created other frameworks for conceptualizing teachers' use of the curriculum (1999, 2000). The first of these frameworks is Remillard's (1999) arenas of curriculum development. Remillard recognizes that the teacher enacts the curriculum through interaction with the text and students in the three major "arenas" of design, construction, and mapping. The design arena involves the way the teacher reads a text. "The factors that figured most significantly in the different ways the teachers read the text were: (a) how each thought about the contents and nature of the mathematical terrain, and (b) the views each held about teaching and learning" (p.325). Here Remillard acknowledges the impact of teachers' beliefs and understandings on how they design instruction.

Each teacher in her study attended to some parts of the text while dismissing others: "Catherine tended to pay attention to suggestions related to exercises and activities on the students' pages. Jackie tended to skip the suggestions related to the activities on the students' pages" (p.325). They also read similar suggestions for different purposes:

> When Catharine looked at a suggestion in the text, she looked for tasks she might appropriate, steps to follow, and things to do… Jackie interpreted similar suggestions in the text as attempts to address particular mathematical ideas or concepts and paid little attention to the actual tasks (p. 325).

In both of these instances of selectively reading the text, the teachers limited their opportunities for learning. They focused on material that was familiar to them and looked for ways of incorporating the text into their familiar styles of teaching. Avoiding the potential opportunities for learning that were presented in the curriculum may not have been intentional on the part of these teachers. However, had there been occasion for critical discourse around the content and pedagogy presented in the curriculum, the

teachers might have been more apt to engage themselves with it in a more cooperative manner.

Remillard's design arena therefore, since it involves the way a teacher reads a text, is a target area for encouraging critical discourse. Challenging the ways that teachers approach curriculum is important for creating opportunities for teacher learning. Furthermore, the design arena precedes and heavily influences the construction arena, which is where the curriculum is enacted in the classroom. The construction arena's primary activity is *task adaptation*, "the unrehearsed adapting and adjusting of tasks in order to facilitate students' work with them" (p. 328). The way teachers adapt tasks is through reading students' performances and improvising in response. This arena can create teacher learning if the teacher allows for it in his/her classroom, that is, if he/she allows for students' questions and responses to draw out and challenge his/her own understanding of mathematical concepts.

While the design and construction arenas involve the day-to-day decisions that directly impact the enacted curriculum (p. 333), the curriculum mapping arena encompasses both, and "involves decisions that effectively define and organize the mathematics curriculum as a whole and determine the content, sequence, and timing of its topics" (p. 333). Curriculum mapping is further broken into two tasks – topic determination and content determination. Breaking the year into broad categories such as fractions, multiplication, etc. is an example of topic determination, and defining specific concepts or skills that are necessary for mastering the topics is content determination.

In the classrooms studied using this framework, the teachers did not actualize opportunities for learning in the curriculum. Remillard attributes this behavior to the way the text was written,

> The text represented the reforms in terms of tasks or activities, focusing merely on the observable aspects of teaching. By not talking *to* teachers, the text failed to address the less visible aspects of teaching, such as decision making, leaving the teachers to draw on practices they were most familiar with (p. 328).

By not addressing teachers' preconceptions of math content and pedagogy, the curriculum left teachers' practices largely unaltered. Teachers adapted the methods of instruction that were familiar to them. The design of the curriculum, then, provides further support of the importance of critical discourse. When working with curriculum that is not targeted towards teacher learning, possible opportunities for learning need to be facilitated for teachers through conversation. This conversation can lead to further self-reflection and thereby a change in practice.

Remillard's (2000) study of the use of a new mathematics text by two fourth-grade teachers introduces another framework for conceptualizing teachers' use of curriculum. She designates categories according to the ways teachers learn, that is, through reading the text, reading students, and reading tasks. Learning through reading the text contains two subcategories – learning through appropriating tasks and learning through inventing tasks. Appropriating tasks involves using tasks as they are presented in the text while making ongoing adjustments. Remillard explains how appropriation led to teacher learning, "It was this process of adjustment, which involved examining students' encounters with the tasks and adapting tasks that prompted Catharine to revise many of her views about the nature of mathematics, her mathematical understandings, and practices" (p. 336).

Learning through inventing tasks similarly requires the teacher to gain a greater understanding of mathematics. By using the text as a source of mathematical and representational ideas from which she adapted her own tasks, the teacher was forced to think through her understandings of mathematics in order to best incorporate them into the tasks. This process "deepened Jackie's understanding of central mathematical ideas in the curriculum and their relations to one another" (Remillard, 2000, p. 338).

Learning through reading students is connected to Remillard and Bryans' (under review) "insights into students learning" which was mentioned earlier as an opportunity for learning. Remillard (2000) illustrates how students' participation in instruction informs teachers while enacting the curriculum and leads to teacher learning:

> The teachers relied on their readings of students particularly when students were struggling. As a result, they found themselves paying close attention to students' thinking in order to help them. Through this process, the teachers often examined mathematical ideas more closely and reconsidered their own views of mathematics and of students' abilities (p. 340).

In this case, the learning occurred as teachers tried to understand students' thinking, which required considerable improvisation and a deep understanding of the mathematical content with which students were struggling. In order to recognize what aspect of the content is troubling the student and provide useful guidance, teachers need to be able to bridge mathematical content to student ability.

Similarly, learning from reading tasks also requires teachers to relate mathematical content to students' abilities. In the instances Remillard describes, teachers thoroughly read tasks in preparation for a class activity in order to anticipate probable student responses and difficulties.

> Catherine spent a great deal of time analyzing the problems herself. She considered what type of thinking they involved, how she would do them herself,

> and how she would articulate the intuitive approaches she used… Catherine's efforts to analyze these tasks enabled her to see their mathematical value and prompted changes in her view of students' abilities (p. 341).

When reading, teachers would look for the mathematical demands and goals of a task (p. 341) and consider how to relate these to students. This type of learning allowed teachers to change both their pedagogical beliefs and mathematical understandings as they were exposed to students' ideas and the content and goals of the curriculum.

A final study that informed the analysis of the case study presented in this paper was Brown's (2002) dissertation on the ideas and beliefs that teachers bring to the curriculum, and in particular his framework of curriculum use. He argues that:

> teachers' use of materials can be characterized as *design* in that use hinges fundamentally on a process of perception, interpretation, and coordination of cognitive and physical affordances of the curricular resources—all in the process of crafting daily instruction. This process is rooted in a dynamic interaction between elements of the curriculum materials and teachers' knowledge, goals, and beliefs (p. 442).

He describes the *pedagogical design capacity* of teachers as "teachers' capacity to perceive and mobilize existing resources in order to craft instructional contexts" (p. 5). This theoretical construct refers to capacity as not only a function of the knowledge that teachers have, but as their ability to accomplish new things with that knowledge (p.451). According to this definition, the pedagogical design capacity of teachers would grow with the frequency of opportunities to learn. Opportunities that challenge teachers to use their knowledge to introduce new activities and understandings to their mathematical and pedagogical repertoire would also increase their design capacity.

Brown also established a continuum of curriculum use. Here he describes the progression:

> at one extreme, the teacher *offloaded* responsibility for guiding instructional activity onto the materials. In these cases, she relied on the materials to support aspects of instruction. At the other extreme, she *improvised* her own strategies for instruction with minimal reliance on the materials. In between, she frequently *adapted* the curriculum resources in ways that reflect contributions of both the materials and personal resources (p.408).

His three identifiers – offloaded, adapted, and improvised – parallel Remillard and Bryans' (under review) three uses – intermittent and narrow, adapting and adopting, and thorough piloting. From left to right on the continuum, opportunities to learn increase as do teachers' pedagogical design capacity. Brown emphasizes the influence of personal resources on teachers' curriculum design. At the same time, as teachers expose themselves to learning opportunities, they acquire more personal resources that can be used in designing instruction.

These models of teacher learning and use of the curriculum have informed this case study which seeks to answer the following questions: How can critical discourse support teachers in learning to use a reform curriculum, such as *Investigations*? How does this learning take place? How is it experienced by one 4th grade teacher? By locating instances of critical discourse in four years of qualitative data on a 4th grade urban elementary school teacher, the case study that follows will contribute to the discussion of teacher learning, inquiry stance, and the importance of teacher beliefs in curriculum implementation.

Methods

About the Study

This research is part of the larger Mathematics PLUS[1] teacher study which included professional development and extensive data collection on teacher and student learning. The pilot of the study began during the 1998-99 school year. In the fall of 1999, the study began full force and continued for four years through the end of the 2002-2003 school year. The research team was led by Janine Remillard (University of Pennsylvania).

About the Site

Carter Elementary School[2] is a K-4 urban elementary school smaller than most local public schools, with approximately 280 students. Due to district desegregation efforts, students from outside of the immediate neighborhood, a low-income predominantly African American community, were permitted to attend Carter, resulting in a student body from a range of ethnic and social class backgrounds. At the time of the study, the students were: 60% African American, 30% White, 7% Asian, and approximately 3% Latino. According to the district, 61% of students were from low-income families. The teaching population was 35% African American and 65% White.

In addition to its desegregation efforts, there are two important facts about Carter that distinguish it from local elementary schools. First there is its history as a progressive school. When it first opened in the 1970s it offered both an open-classroom track and a formal or traditional track. This structure has yielded to a single track system that encourages the practices formerly associated with the open track, such as integrated theme studies and literature-based reading instruction (Remillard and Bryans, under review).

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[1] This research was funded by the National Science Foundation (grant # REC-9875739). The views expressed in this paper are the author's and are not necessarily shared by the grantors.

[2] All names for the school and teachers are pseudonyms.

Secondly, Carter upholds a commitment to teacher development, and in particular, to improving mathematics teaching and learning. The principal during the 1997-98 school year supported these efforts. During a summer professional development program in 1998, more than half of the teachers at the school decided to adopt a new curriculum, *Investigations in Number, Data, and Space* (TERC, 1998). The following summer, most of the teachers and the principal attended a week-long session sponsored by the curriculum developers that introduced teachers to the goals and content of the curriculum.

About the Curriculum

Investigations in Number, Data, and Space (TERC, 1998) was developed with support from the National Science Foundation, in accordance with the NCTM *Standards* (1989, 1991) and with teacher development in mind. The curriculum "speaks" directly to teachers: "Because we believe strongly that a new curriculum must help teachers think in new ways about mathematics and about their students' thinking processes, we have included a great deal of materials to help you learn more about both" (p 6). It includes mathematical explanations, possible student responses and examples of student work, summaries on relevant research, and suggestions for assessment and implementation.

Data Collection and Analysis

Data collected for the Mathematics PLUS study includes regular classroom observations, teacher interviews, video-taped documentation of each study group meeting, and observations and video-taped clinical interviews of four focus students in each classroom. Data on the focus students was not analyzed for this paper. This case study draws upon one teacher's interviews over four years, observations of her

classroom, and videos of select study group meetings. The analysis was supplemented with input from observers and the lead researcher.

Laura Schwartz, the teacher in this case study, is a 4th grade teacher. Laura was in her 3rd year of teaching when the study began, and she had spent all of them at Carter. During the first year of the study, her classroom was a focus classroom and therefore was observed daily for one week every two months. She was interviewed four times throughout the school year. Over the remaining three years of the study Laura Schwarz was interviewed three times each year and her class was observed about once a month. During formal observations, the observer tape recorded the lesson and also took field notes, which were then used to create a transcript of the lesson. Interviews were tape recorded and transcribed. Questions attempted to elicit how teachers felt about mathematics, teaching, student learning, the curriculum, teacher learning, and the study group.

The first step of analysis involved reviewing each of Laura's interview transcripts and logging instances where she mentioned teacher beliefs, learning, math, and the impact of the study group. Then, through multiple viewings, codings, and transcriptions of key segments of the study group videos, I noted instances of critical discourse in Laura's learning with the group. Using the research on teacher beliefs and use of curricula, I examined progression over time in Laura's beliefs and understandings as portrayed in her own talk about practice, and in her actions during study group. In the section that follows, I offer an analysis of Laura's use of critical discourse as a learning opportunity.

Results and Discussion

Study group meetings were held monthly and were attended by all participating teachers at Carter Elementary. Janine Remillard, the PI of the study, led the meetings, but requested feedback and direction from the participants. Oftentimes, study group meetings would begin with a mathematical activity taken or adapted from *Investigations*, and teachers would engage in exploring their own math understanding as well as investigate the possibilities for student learning within the activity. Laura was a vocal and eager participant in the meetings, and her involvement in the discussions revealed a great deal about her beliefs and understandings of teaching.

During interviews over the four years, Laura discussed freely the impact that being a participant in the research study and attending the study group meetings had on her teaching. She particularly valued the relationships that she developed with her colleagues who also participated in the study. It is in these revelations that Laura uncovered the importance that critical discourse had in her learning and how it contributed to her change over time. Four major themes emerged in Laura's interview responses. The themes are interconnected, but in order to see the dimensions of change that occurred over the four years, I separate them here.

First, Laura was eloquent in her descriptions of the challenges of teaching a new curriculum, including adapting to the philosophy of teaching that it holds, as well as struggling with the lack of resources and other difficulties associated with teaching in an urban school. Secondly, Laura was very conscious about the changes that occurred in her math instruction. Deeply embedded in this second theme are the two final themes – changes in how Laura thought about mathematics and the ways she accounted for student

understanding in her classroom. The value of the study group and critical discussion is again revealed in the way she and her colleagues dealt with the challenges.

Growing with the New Curriculum

When Laura first began teaching at Carter, which was three years before the study, she was given her choice of curriculum. She opted for the Scott-Foresman series, a traditional curriculum that focused on standard algorithms, loads of practice problems, and a teacher-centered approach to teaching. In the following excerpt from an interview, Laura reminisces about that curriculum:

> Um, pretty much as a beginning teacher, I was seeking some program to do. And that book required me to have everybody open the workbook, turn to the same page, and go through extremely quickly, introducing something, practicing it, introduce the next thing … There was no deep meaningful conversation about anything to be had. It was simply, "Go through this massive amount of practicing and development of skills." And it was the most traditional book I'd ever seen. (Teacher Interview 10.21.01).

Laura was disappointed with the traditional curriculum. The traditional books offered many extensions of lessons, but did not provide her with a sense of consistency throughout the lessons. She compares how she felt using that curriculum to the way she feels about using *Investigations*:

> And so, I just floundered for a year. And then we started the *Investigations,* and I flounder constantly in Investigations, but I'm very happy. I'm very happy floundering (Teacher Interview 10.21.01).

In *Investigations*, the curricular materials are arranged around units that break topics into activity-centered "investigations" where students uncover mathematical ideas and then regroup as a class to discuss their findings. The "floundering" Laura mentioned resulted from switching from a teacher-centered approach to one that included much more interaction on the students' part. Making this switch required significant reflection and

commitment from Laura. She found that the study group supported her in making this change.

During the second year of the study, Laura reminisced with her colleagues about her first year of teaching. At that time, she had been grappling with the idea of constructivist teaching; she wished to use it in her practice but found herself struggling to maintain control of her classroom. She commented on how the study group helped her to keep focused on the goals.

> …the idea was no matter how much philosophically I might want to go into constructivist learning, as I'm tripping over my 32 children as I'm going to sharpen a pencil, I turn into "I'm the teacher and you have to listen to me!" And this [the study group] continually regrounds me in, "the sooner I get kids working on their math and coming back hot to talk about it the safer we all are" because I won't trip over anybody and I don't lecture anybody and the learning is happening … and back here [in the study group meetings] we had to ask each other…what's the learning we're looking for? ... developmentally what CAN the kids do? And that's where looking together was helpful (Study Group Meeting 02.12.02).

The sort of support Laura spoke about in the study group resurfaced in her interview responses. In the passage that follows, Laura reflected on the first year of the study, when she was beginning to get a feel for the *Investigations* curriculum. As Laura became more familiar with the intentions of the curriculum, and as she reflected on her teaching, she was able to recognize discrepancies between the two. She established goals for the following year that would bring her practice more in line with the objectives of the curriculum:

> Last year [the first year of the study, and Laura's first year using *Investigations*] I wanted to get the activities done. Activities are seductive. They're useful, but it's in the conversations not the game that deep learning takes place. The strategies need to become tangible. My goals for next year? Well I'm a little more familiar with the program. It's not just to get activities going. I'm going to stick with going deep and get to the conversation. The conversation spawns new activities. The strategies spawn new activities. (Teacher Interview 06.00.00)

Her commitment to using discussion effectively to draw out students' understandings of mathematics reflects her dedication to changing her practice to match the goals of the curriculum. Next, I examine how Laura's instructional practice changed over the course of the study.

Changes in Math Instruction

Laura's hesitation over how to use the constructivist model in the *Investigations* curriculum in her classroom, which she voiced in the second year of the study, all but disappeared by the fourth year. The excerpt below (from a final interview) reveals that this hesitation had been replaced with a vision of teaching that embodied the goals of *Investigations* and the NCTM Standards:

> I think a rigorous classroom is set up so that it moves seamlessly, alright, fumbly, but it moves from hands on activities, to conversations, to concrete work, to more concrete work, to more hands on activities, to harder work, to slower work, and there is just a constant high level of demand on thinking and engagement and I'm getting closer to it (Teacher Interview 04.22.03).

Over the four years, Laura became increasingly more decisive about this goal and, in the process, changed both the way she approached mathematics and the way she conducted mathematics lessons in her classroom.

In her interview responses, Laura repeatedly emphasized the importance that the study group held for her regarding changes in how she taught mathematics. At the most superficial level, Laura commented on how the frequency of observers in her classroom, either observing her teaching or her students' learning, ensured that math instruction took place a minimum of five hours per week (Teacher Interview 05.28.02). Furthermore, in numerous interviews over the four years, Laura alluded to her thankfulness for the presence of research team members in the class as "grownups in the room who are

putting themselves at children's height" (Teacher Interview 05.28.02). Having additional adults present to challenge students and keep them on task was helpful to Laura; with a class size averaging thirty students, she often found it burdensome to meet the diverse needs of all her students.

When asked to share what she saw as the purpose of the study group in the second year of the study, Laura responded with a statement that sounded very reminiscent of the types of learning and support argued in the literature on teacher learning:

> So to me, the purpose of a study group is, to, [pause, clears throat], have an ongoing conversation that [pause] um, asks questions around the teaching of and the learning of how to teach math… the purpose is to support the teachers in becoming the best math teachers they can be. In whichever way that helps that. (Teacher Interview 04.19.01).

For Laura, the study group provided support and content-specific interactions that guided her development as a math teacher. The "ongoing conversation" she described encapsulates the concept of critical discourse. Through her active participation in critical discourse with her colleagues, Laura was able to reflect on her teaching and make connections between new material and her own pedagogical and mathematical beliefs.

Laura was particularly eloquent in an interview during the fall of the second study year, where she compared her pre-service preparation to the skills she had developed since being involved with the *Investigations* curriculum. Here she describes the assumptions of teacher preparation programs,

> I've said it before, and I'll say it again: I had no program. I am not a teacher who, um, was trained in anything in how to teach math, other than the exact thinking that is modeled in Investigations and modeled in Janine's study groups. The presumption at the University seems to be that any intelligent person who has been through the school system knows how to teach traditionally, because he experienced it as a kid, which I find insulting and bizarre…I could not even tell you what fourth grade math was supposed to be. (Teacher Interview 11.29.00).

Laura's struggle to find a teaching style that suited her personal beliefs but also coincided with the goals of the curriculum is evident in this excerpt. It is particularly interesting that she credited the study group and the curriculum itself as her "training" in how to teach math. Next, she described the strides she made in deciding what to expect of students and what to include in instruction:

> I am learning better how to identify and know what the skills are that build up to the operations of addition, subtraction, multiplication, division ... And, I don't in any way see that I'm having to stop and teach it, um, in a way separate from what we're doing. [big sigh] What a shift. It is totally a shift. (Teacher Interview 11.29.00).

The curricular goals, students' cognitive development, and the continuity and circular nature of math learning all came together for Laura. The above quote reveals her surprise at the degree to which these elements had caused a shift in her thinking and instructional practice.

Changes in Understandings of Mathematics, Both Her Own and Those of Her Students

Along with changes in math instruction, Laura's understandings about mathematics also changed over the course of the study. After the first summer workshop and at the very start of the first year of the study, Laura told an interviewer that she was more excited about mathematics:

> The summer workshop provided more opportunities for making connections, and the math study group. Also, both of those experiences showed me that when adults do math, that it's just fun. I come to this year with high hopes that my familiarity will create more ease with the cumbersome aspect of starting up units and learning about units. (Teacher Interview 09.29.99).

In an interview three years later, where she was asked to take a stance on one side of the debate of basic skills versus conceptual understanding, she revealed a more nuanced perception of the intricacies of math teaching. Her desire to focus on the concepts,

however, was impeded by her lack of familiarity with them. She did attribute her learning to the study group, but acknowledged the need for more exploration:

> Well…focusing on conceptual understanding means that the teacher needs to understand what the concepts are, and thanks to math study group, some of us have at least a tiny handle on that, but it's still fairly huge and out there…it is not…despite having been through the Master's program…, some of us are still major ignoramuses and don't even know what we're talking about when we're talking about the concepts… So I'm picking it up through math study, I'm picking it up piece by piece and building little bits. (Teacher Interview 09.17.02).

Despite their pre-service training, Laura and her colleagues were not confident in their ability to explain the meanings behind mathematical concepts. The study group provided them with a space to explore those concepts and to develop confidence. In this way, critical discourse about mathematics helped Laura and her colleagues to develop a greater understanding of mathematics.

What Laura described as being most interesting and useful to her in the study group meetings generally revolved around mathematics and students' understanding. Laura is from an academic family, and called herself a "math-a-ma-holic" and so was inclined to challenge herself to learn new methods and delve into deeper understandings of mathematics concepts. In one of the final interviews of the study, Laura explained how she had changed the way she thought about math:

> It's interesting. Of course there's a way that I'm more aware. I have a meta-state about my own working on math. I recognize my own ways of solving problems and what strategies I used to avoid, the things that didn't come easy to me. For a long time our focus was on all grades all trying to help the kids to develop to solve things in multiple ways and to use the Investigations methods. And at this time, they come to me as second nature for the bulk of the class. (Teacher Interview 06.08.03)

This statement is an example of the kind of learning opportunities discussed in the work of Remillard and Bryans (under review). What Laura described is a case of learning

through the "exploration of mathematics." By analyzing the methods she was most comfortable with, she became familiar with her own understanding of concepts and could approach students' understandings in a new light. Thinking about mathematics was not new for Laura, but the attention to her own understanding, *i.e.* the "meta-state" of her own working on math, was important in allowing her to relate to her students.

Another example of the sort of self-reflection that Laura engaged in while working through math problems on her own emerged in another interview:

> I tend to enjoy deciding how I'm going to express something in a certain way and then asking myself what does that show me? Or what does that mean? (Teacher Interview 05.28.02).

In reconsidering her initial approaches to mathematics, Laura gave particular attention to the benefits and limitations of using a particular method over another. Students' understandings played heavily into these decisions. This sort of learning aligns with Remillard and Bryans' (under review) "insights into students' thinking." By considering students' reactions to her methods of instruction, Laura allowed their ideas to influence her decision-making.

One of the things Laura mentioned as being valuable was looking at students' work and analyzing what was going on with it (Teacher Interview 06.04.01). She claimed that the children are "in a lot of ways, experts at doing the kind of work *Investigations* asks for" (Teacher Interview 02.09.02). From talking over students' work with her colleagues, Laura gained insight into the sort of responses that might surface in her class. She developed expectations of what was grade level material, and could hold her students to these high standards.

Finally, Laura shared in one of the last interviews her reflections on the importance of the study group. She captures the essence of critical discourse and communicates its importance in her development as a teacher:

> The study group is a very important part of my work as a teacher because it's a professional think tank on the math program. It's a place where we check in and look to understand what we're doing. It's a place where I can share the confusion, frustration, or concerns or ask questions. I hear about the other teachers and their math practice. So above and beyond the fact that it provides a thoughtful connecting place, it's where I get to step outside of my classroom and think about the math program with other people. So that's invaluable (Teacher Interview 06.08.03).

The comfortable atmosphere of the study group allowed her to explore the dimensions of her teaching practice, mathematics understandings, students' interpretations and the interconnectedness between these three realms.

Implications for Professional Development

Laura's experience using *Investigations* and her participation in the study group revealed what might be possible for teacher learning on a large scale. The use of critical discourse among Laura and her colleagues aided her in reflecting on her practice in ways that contributed to her learning and affected her teaching. In the study group, Laura was supported by her fellow teachers who were interested in analyzing their practice and the mathematical content presented in the new curriculum. The support from her colleagues, which critical discourse provided, helped Laura to develop goals and a style of instruction that was in line with the goals and instruction presented in the curriculum.

If reform-based curriculum is intended to alter the teaching practices of classroom teachers like Laura then their development needs to be an integral part of the implementation of that curriculum (Wilson & Berne, 1999). A more coherent program of implementation of reform-based curriculum would include sustained, ongoing teacher

development that encourages teacher learning. Providing spaces like the study group where teachers can engage in critical discourse with each other about the nature of the curriculum, their teaching practice, and their understandings of the mathematics concepts presented in the curriculum, could aid in the successful implementation of a reform curriculum (Cobb & Yackel, 1991; Szydlik, et al., 2003; Hammerman, 1995). In short, if teachers are going to be asked to change their teaching, they should be supported in their efforts to do so.

Several studies on teacher preparation inform this argument. A decade ago, Stoddart et al. (1993) conducted a study exploring the depth of understanding of math and science content among elementary school teachers. Their findings showed that the majority of elementary school teachers they studied did not have a strong understanding of mathematics. Furthermore, they asserted that teachers tended to teach mathematics and science just as they had been taught. "Improving mathematics and science instruction may require teacher candidates to relearn their subject matter knowledge in a way that enables them to organize it meaningfully, learn its method of inquiry, and to see its significance in everyday life" (p. 232). Stoddart et al. also concluded that subject matter courses at the college level especially, did not provide this sort of exploration into the subject, and that methods of teaching classes often assumed mastery of content rather than fill this role. This study found that more is needed in terms of professional development beyond teacher preparation programs to provide elementary school teachers with a depth of mathematics understanding.

Deborah Ball (1994) reached similar conclusions in her work on teacher learning and the mathematics reforms. When discussing with teachers the turning point at which

they stopped pursuing mathematics education, she discovered, “Rather than becoming critical of the way we “school” mathematics, they often assume that their experiences are due to their own mathematical lacks and to the inherently useless content of mathematics” (p. 8). In this way, teachers, as products of the system they are being solicited to reform, perpetuate mathematics education void of meaning.

Ball goes on to critique professional development and propose a new agenda for such programs. She argues that traditional professional development programs (such as in-service programs) consist of presentations of answers and focus on providing teachers with a mass amount of material from which they can find their own style. “This individualism not only makes it difficult to develop any sense of common standards, it also makes it difficult to *disagree*. Masking disagreements hides the individual struggles to practice wisely, and so removes and opportunity for learning” (p. 14). Ball and others (Ball & Cohen, 1995; Hammerman, 1995; Jones, 1995; Stoddart, 1993;Wubbels, et al., 1997) would prefer to see more interactive and constructivist learning among teachers that allows them to create new ideas and strategies for learning and teaching, consider how other resources might be useful, and be innovative in generating new knowledge (Ball, 1994).

A paper by Sonia Woodbury (2000) casts teachers’ thinking at the heart of mathematics educational reform. She brings up the importance of the alignment between reform goals and teachers’ view of the need for reform. She claims that “reform messages should more explicitly challenge teachers to examine their pedagogy and their beliefs in relation to reform images of teaching and learning mathematics” (p. 43). Discussion between teachers about the nature of reform might clarify for teachers the

intended purpose for making changes in their teaching styles. Moreover, discussion between teachers about practice will at the very least lead to reflection over their current practice and potentially influence positive change.

Woodbury, Ball, and others have suggested alternative professional development materials to encourage critical reflection among teachers in the face of reform movements. One such method is using video tapes of teachers in action to engage teachers in self-critique as well as help them to see the possibilities of alternative teaching methods. Another strategy for professional development that removes the time constraints of busy schedules is digital correspondence through e-groups and e-mail. Discussions on critical issues, requests for materials, assistance, or expertise, or sharing joys and concerns of the classroom could provide teachers with a community of support that could lead to honest reflection and discussion.

Conclusion

In this paper, I explored the importance of critical discourse in the experience of one fourth grade teacher as she learned to use the standards-based curriculum, *Investigations*. This case study demonstrated how critical discussion about mathematics might promote teacher learning and lead to teaching practices that are more compatible with the student learning outcomes presented in the NCTM Standards. Specifically, the study group presented Laura with the opportunity to participate in discussion with her colleagues. This critical discourse enabled her to consider the merits and demerits of her practices, beliefs, and understandings accordingly, and make connections between her understanding of new content and her pedagogical beliefs. Furthermore, Laura's use of critical discourse in the study group enabled her to grow with *Investigations*, make

changes in her math instruction, and make changes in understandings of mathematics, both her own and those of her students.

This case study has implications for the professional development of teachers. It shows how participation in critical discourse can support teachers in learning to use a reform-based curriculum. Since reform-based curricula demand a transition from traditional teaching methods to more student- and activity-centered instruction, it is necessary for teachers to reexamine their beliefs and interact with mathematics in ways that they will be expected to teach (Ball, 1994; Hammerman, 1995; Lloyd, 2002; Russel et al., 1995; Wilson & Berne, 1999; Woodbury, 2000; Wubbels et al., 1997). In short, critical discourse about mathematics and teaching provides teachers with the learning opportunities to support the transition from traditional teaching methods to standards-based instruction. Incorporating professional development programs that include critical discourse into reform curriculum programs could lead to the implementation of classroom practices that allow students to "confidently engage in complex mathematical tasks" as "flexible and resourceful problem solvers" (NCTM, 2002) – goals imagined by the developers of the NCTM standards.

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